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ENVIRONMENTAL RADIOACTIVITY IN THE FAROES IN 1979

A. Aarkrog and J. Lippert

Abstract. Measurements of fallout radioactivity in the Faroes in 1979 are presented. Strontium-90 (and ^{137}Cs in most cases) was determined in regularly collected samples of precipitation, grass, milk, fish, sea water, bread and drinking water. In addition, analyses were made of spot samples of lamb, sea birds, potatoes, sea plants, vegetables, eggs, and human bone. Estimates are given of the mean contents of ^{90}Sr and ^{137}Cs in the human diet in the Faroes in 1979.

INIS Descriptors

[0] DIET, ENVIRONMENT, EXPERIMENTAL DATA, FAROE ISLANDS, FISHES, FOOD, FOOD CHAINS, GLOBAL FALLOUT, GRAPHS, MILK, PLANTS, RADIOACTIVITY, SEA WATER, SHEEP, TABLES

[1] ATMOSPHERIC PRECIPITATIONS, BONE TISSUES, DRINKING WATER, MAN, STRONTIUM 90

[2] CESIUM 137

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ABBREVIATIONS AND UNITS

J: joule: the unit of energy; 1 J = 1 Nm (= 0.239 cal)
Gy: gray: the unit of absorbed dose = 1 J kg^{-1} (= 100 rad)
Sv: sievert: the unit of dose equivalent = 1 J kg^{-1} (= 100 rem)
Bq: becquerel: the unit of radioactivity = 1 s^{-1} (= 27 pCi)

cal: calorie = 4.186 J
rad: 0.01 Gy
rem: 0.01 Sv
Ci: curie: $3.7 \cdot 10^{10}$ Bq (= $2.22 \cdot 10^{12}$ dpm)

T: tera: 10^{12}
G: giga: 10^{9}
M: mega: 10^{6}
m: milli: 10^{-3}
μ: mikro: 10^{-6}
n: nano: 10^{-9}
p: pico: 10^{-12}
f: femto: 10^{-15}
a: atto: 10^{-18}

cap.: caput: (per individual)
TNT: trinitrotoluol; 1 Mt TNT: nuclear explosives equivalent to 10^{9} kg TNT.

cpm: counts per minut
dpm: disintegrations per minut
OR: observed ratio
CF: concentration factor
FP: fission products
μR: micro-roentgen, 10^{-6} roentgen
S.U.: pCi ^{90}Sr (g Ca)$^{-1}$
O.R.: observed ratio
M.U.: pCi ^{137}Cs (g K)$^{-1}$

V: vertebrae

m: male

f: female

nSr: natural (stable) Sr

eqv. mg KCl: equivalents mg KCl: activity as from 1 mg KCl (~0.88 dpm)

S.D.: standard deviation: $\sqrt{\frac{\Sigma(\bar{x}-x_i)^2}{(n-1)}}$

S.E.: standard error: $\sqrt{\frac{\Sigma(\bar{x}-x_i)^2}{n(n-1)}}$

U.C.L.: upper control level

L.C.L.: lower control level

Δ: one standard deviation due to counting

S.S.D.: sum of squares of deviation: $\Sigma(\bar{x}-x_i)^2$

f: degrees of freedom

s^2: variance

v^2: ratio between the variance in question and the residual variance

P: probability fractile of the distribution in question

η: coefficient of variation, relative standard deviation

ANOVA: analysis of variance

A: relative standard deviation 20-33%

B: relative standard deviation >33%, such results are not considered significantly different from zero activity

B.D.L.: below detection limit

In the significance test the following symbols were used:

* : probably significant (P > 95%)

** : significant (P > 99%)

***: highly significant (P > 99.9%)

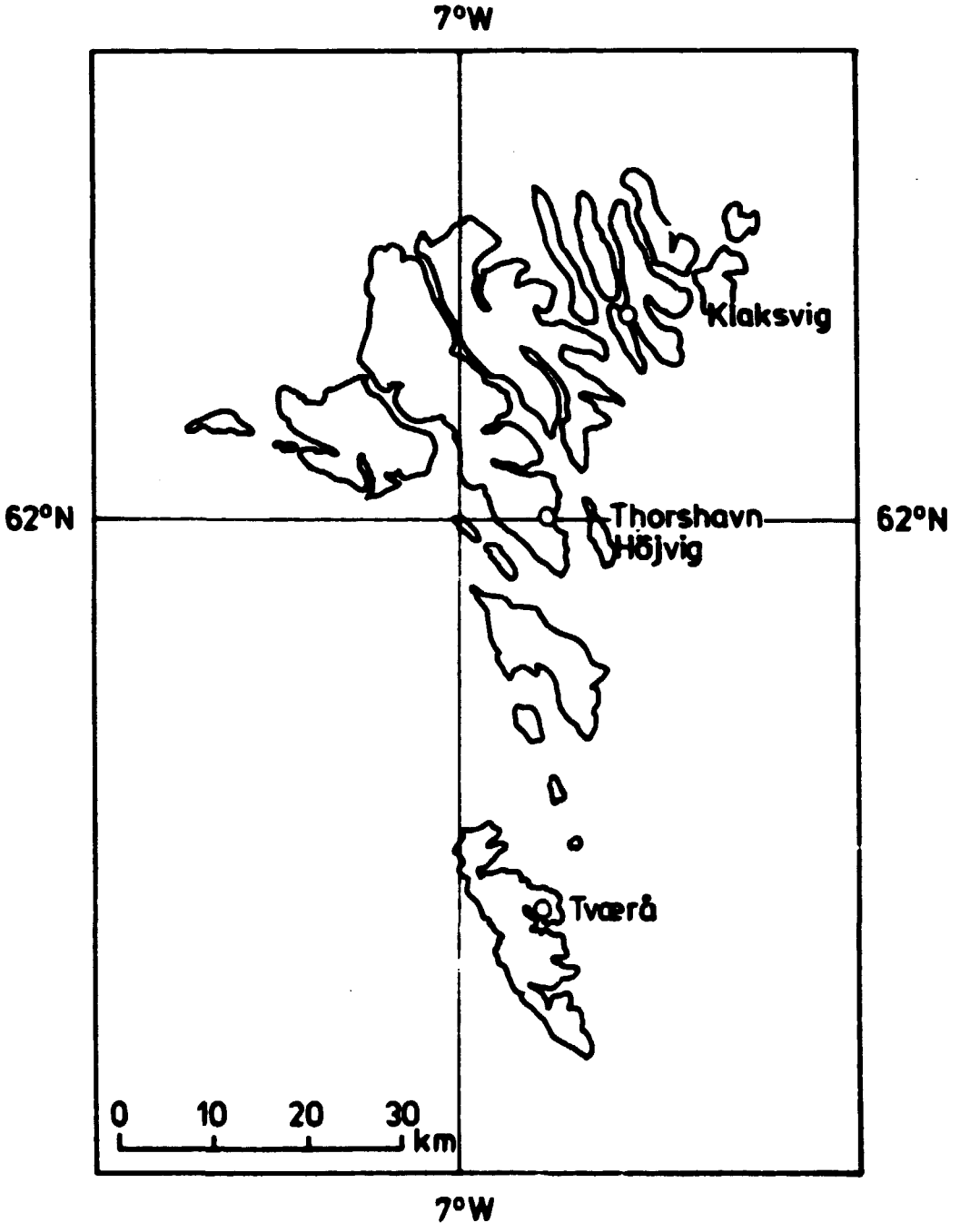

Fig. 1. The Faroese Islands

1. INTRODUCTION

1.1.

The fallout programme for the Faroes, which was initiated in 1962[1)] in close co-operation with the National Health Service and the chief physician of the Faroes, was continued in 1979. Samples of human bone were obtained in 1979 from Dronning Alexandrine's Hospital in Thorshavn.

1.2.

The present report will not repeat information concerning sample collection and analysis already given in Risø Reports Nos. 64, 86, 108, 131, 155, 181, 202, 221, 246, 266, 292, 306, 324, 346, 361, 387 and 404[1)].

1.3.

The estimated mean diet of the Faroese as used in this report is still based on the estimate given by Professor E. Hoff-Jørgensen, Ph.D., in 1962.

1.4.

The present investigation was carried out together with corresponding examinations of fallout levels in Denmark and Greenland, described in Risø Reports Nos. 421[2)] and 423[3)], respectively.

2. RESULTS AND DISCUSSION

2.1. Strontium-90 in precipitation

Table 2.1 shows the ^{90}Sr content in precipitation collected at Højvig (near Thorshavn) and Klaksvig in 1979. The amount of fallout at Klaksvig was a factor of 1.6 greater than that found at Højvig.

The ^{90}Sr fallout in 1979 was approx. 0.4 times of the 1978 levels in the Faroes. In Denmark the 1979 levels were 0.36 times the 1978 levels[2)].

Table 2.1.A. Strontium-90 in precipitation in the Faroes in 1979

	Höjvig		Klaksvig	
	pCi $^{90}Sr\ l^{-1}$	mCi $^{90}Sr\ km^{-2}$	pCi $^{90}Sr\ l^{-1}$	mCi $^{90}Sr\ km^{-2}$
Jan	0.35	0.043	0.46	0.067
Feb	0.53	0.030	0.65	0.052
March	0.54	0.054	0.50	0.101
April	0.63	0.064	0.61	0.066
May	0.49	0.026	0.33	0.089
June	0.43	0.022	0.23	0.041
July	0.42	0.026	0.31	0.015
Aug	0.28	0.030	0.22	0.035
Sept	0.20	0.022	0.22	0.035
Oct	0.179	0.023	0.173	0.039
Nov	0.133	0.022	0.092	0.025
Dec	0.122	0.015	0.128	0.033
1979	$\bar{x}$ 0.32	Σ 0.377	$\bar{x}$ 0.28	Σ 0.598
		Σ_{mm} 1187		Σ_{mm} 2107

Table 2.1.B. Strontium-90 in precipitation in the Faroes in 1979

	Höjvig		Klaksvig	
	Bq $^{90}Sr\ m^{-3}$	Bq $^{90}Sr\ m^{-2}$	Bq $^{90}Sr\ m^{-3}$	Bq $^{90}Sr\ m^{-2}$
Jan	12.8	1.60	17.1	2.54
Feb	19.5	1.10	24.2	1.91
March	19.9	1.99	18.7	3.73
April	23.2	2.37	22.5	2.42
May	18.0	0.95	12.3	3.31
June	15.9	0.83	8.9	1.50
July	15.5	0.94	11.4	0.57
Aug	10.2	1.12	8.2	1.29
Sept	7.5	0.81	8.2	1.30
Oct	6.6	0.84	6.4	1.44
Nov	4.9	0.83	3.4	0.94
Dec	4.5	0.54	4.7	1.23
1979	$\bar{x}$ 11.7	Σ 13.92	$\bar{x}$ 10.5	Σ 22.18
		Σ_m 1.187		Σ_m 2.107

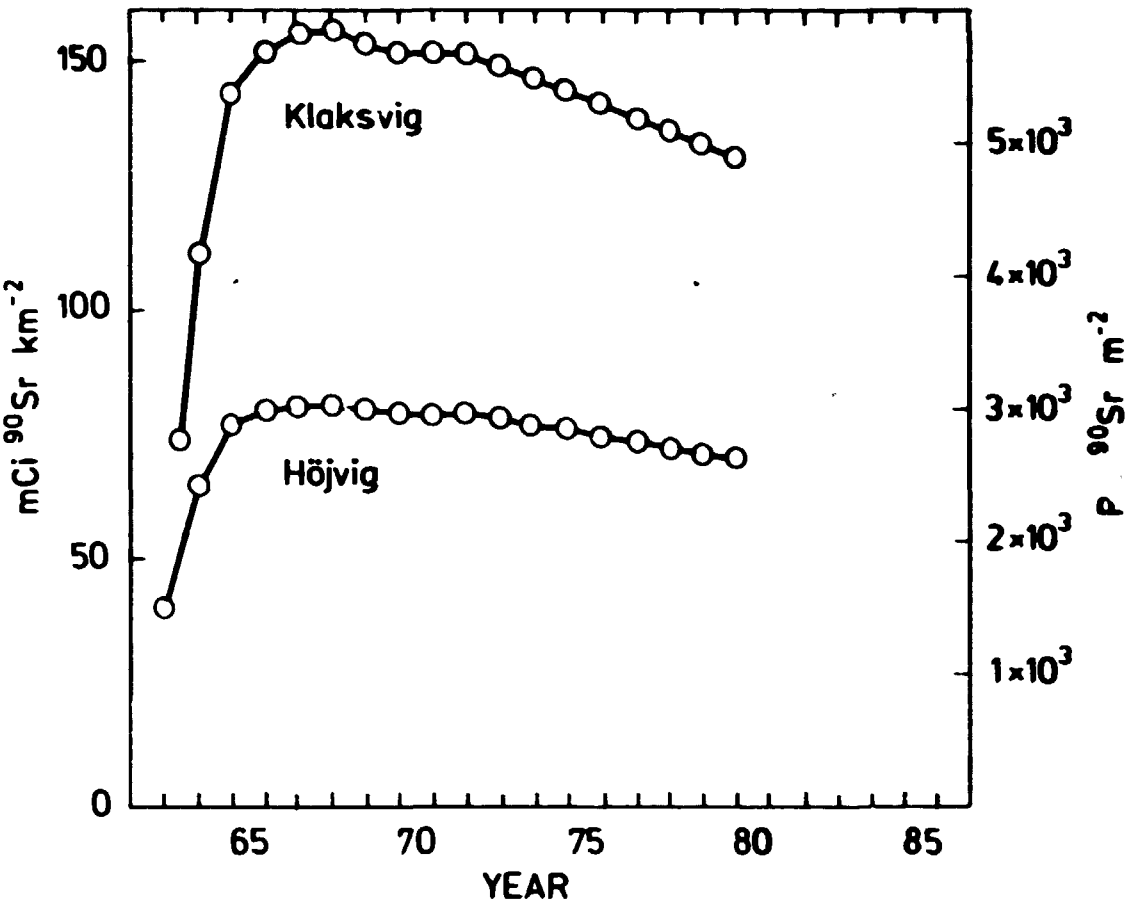

Fig. 2.1. Accumulated ^{90}Sr at Klaksvig and Højvig calculated from precipitation measurements since 1962. The accumulated fallout by 1962 was estimated from the Danish fallout data (cf. Risø Report No. 403[2], Appendix D) and from the ratio between the ^{90}Sr fallout at the Faroese stations and the fallout in Denmark in the period 1962-1974.

2.2. Strontium-90 and Cesium-137 in grass

Grass samples were collected near Thorshavn in 1979. Table 2.2 shows the results. The 1979 S.U. level in grass was nearly equal to the 1978 level. As compared with Danish grass in 1979[2] we found the S.U. level in the Faroese grass to be higher by a factor of approx. 9 in the summer months.

Table 2.2.A. Strontium-90 and Cesium-137 in grass from Thorshavn 1979

Month	pCi ^{90}Sr kg^{-1}	pCi ^{90}Sr (g Ca)$^{-1}$	pCi ^{137}Cs kg^{-1}	$^{137}Cs/^{90}Sr$
June	76	145	250	3.29
September	118	310	370	3.14

Table 2.2.B. Strontium-90 and Cesium-137 in grass from Tórshavn 1979

Month	dq ^{90}Sr kg^{-1}	dq ^{90}Sr (kg Ca)$^{-1}$	dq ^{137}Cs kg^{-1}
June	2.3	5,400	9.1
September	3.4	11,500	13.5

2.3. Strontium-90 and Cesium-137 in milk

As in previous years[1], weekly samples of fresh milk were obtained from Thorshavn, Klaksvig, and Tvørå. Strontium-90 and ^{137}Cs were determined in bulked monthly samples.

Table 2.3.1 shows the results and Tables 2.3.2, 2.3.3 and 2.3.4 the analysis of variance of the S.U., M.U., and pCi ^{137}Cs l^{-1} figures respectively. As also observed in previous years, the variation between locations was highly significant for ^{137}Cs as well as for ^{90}Sr. The highest ^{90}Sr levels were found in the milk from Tvørå. Thorshavn showed lower ^{137}Cs concentrations in milk than Klaksvig and Tvørå.

Figure 2.3.1 shows the quarterly S.U. values and Fig. 2.3.2 the quarterly pCi ^{137}Cs l^{-1} levels since 1962. The annual mean values for 1979 were 8.4 S.U. (~ 10 pCi ^{90}Sr l^{-1}) and 87 M.U., or 151 pCi ^{137}Cs l^{-1}, i.e. the ^{90}Sr levels in 1979 were nearly unchanged from 1978, while the ^{137}Cs levels were approx. 80% of the 1978 mean levels.

Table 2.3.1.A. Strontium-90 and Cesium-137 in Faroese milk in 1979

Month	Thorshavn			Klaksvig			Tvørá			Mean		
	pCi ^{90}Sr $(g\ Ca)^{-1}$	pCi ^{137}Cs l^{-1}	pCi ^{137}Cs $(g\ K)^{-1}$	pCi ^{90}Sr $(g\ Ca)^{-1}$	pCi ^{137}Cs l^{-1}	pCi ^{137}Cs $(g\ K)^{-1}$	pCi ^{90}Sr $(g\ Ca)^{-1}$	pCi ^{137}Cs l^{-1}	pCi ^{137}Cs $(g\ K)^{-1}$	pCi ^{90}Sr $(g\ Ca)^{-1}$	pCi ^{137}Cs l^{-1}	pCi ^{137}Cs $(g\ K)^{-1}$
Jan	7.6±0.2	77	44	6.8±1.0	155	86	8.6±0.6	195	102	7.7	142	78
Feb	6.7	106	64	8.9	120	73	11.9	240	136	[illegible].2	156	91
March	8.6	133	66	9.5	230	127	11.0	186	114	9.7	182	102
April	7.7±1.1	72	40	8.2±1.1	154	86	9.8±1.3	198	120	8.6	141	82
May	8.7	72	37	10.6	230	132	10.4	139	76	9.9	148	8[illegible]
June	6.2	52	32	7.4	173	107	8.0	141	75	7.2	122	71
July	8.1±1.0	97	59	7.2±0.5	172	108	10.1±0.5	195	106	8.5	155	91
Aug	8.3	95	59	4.2	200	119	12.4	250	146	8.3	182	108
Sept	8.2±0.6	122	65	8.4±1.4	187	119	11.0±0.2	270	155	9.2	193	113
Oct	8.3	98	56	7.4	189	112	9.5	189	112	8.4	159	94
Nov	7.1	61	34	6.3	144	79	8.0	185	102	7.1	130	72
Dec	5.7	59	30	8.3	125	68	6.8	139	80	7.0	107	59
Mean	7.6	87	49	7.8	173	101	9.8	194	110	8.4	151	87

Table 2.3.1.B. Strontium-90 and Cesium-137 in Faroese milk in 1979

	Thorshavn			Klaksvig			Tvørd			Mean		
	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs m^{-3}	Bq ^{137}Cs (kg K)$^{-1}$	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs m^{-3}	Bq ^{137}Cs (kg K)$^{-1}$	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs m^{-3}	Bq ^{137}Cs (kg K)$^{-1}$	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs m^{-3}	Bq ^{137}Cs (kg K)$^{-1}$
Jan	280	2900	1640	250	5700	3200	320	7200	3800	280	5300	2900
Feb	250	3900	2400	330	4500	2700	340	9000	5000	340	5800	3400
March	310	4900	2500	350	8400	4700	410	6900	4200	360	6700	3800
April	290	2700	1490	300	5700	3200	360	7300	4400	320	5200	3000
May	320	2600	1380	390	8600	4900	380	5100	2800	370	5500	3000
June	230	1910	1170	270	6400	4000	290	5200	2800	270	4500	2600
July	300	3600	2200	270	6400	4000	370	7200	3900	310	5700	3400
Aug	310	3500	2200	160	7400	4400	460	9300	5400	310	6700	4000
Sept	300	4500	2400	310	6900	4400	410	10000	5700	340	7100	4200
Oct	310	3600	2100	270	7000	4200	350	7000	4100	310	5900	3500
Nov	260	2300	1240	230	5300	2900	300	6900	3800	260	4800	2600
Dec	210	2200	1110	310	4600	2500	250	5100	2900	260	4000	2200
Mean	280	3200	1810	290	6400	3800	360	7200	4100	310	5600	3200

Table 2.3.2. Analysis of variance of ln pCi ^{90}Sr $(g\ Ca)^{-1}$ in Faroese milk in 1979 (from Table 2.3.1.A)

Variation	SSD	f	s^2	v^2	P
Between months	0.540	11	0.049	1.575	-
Between locations	0.648	2	0.324	10.394	> 99.9%
Months × locations	0.685	22	0.031	1.354	-
Remainder	0.276	12	0.023		

Table 2.3.3. Analysis of variance of ln pCi ^{137}Cs $(g\ K)^{-1}$ in Faroese milk in 1979 (from Table 2.3.1.A)

Variation	SSD	f	s^2	v^2	P
Between months	1.411	11	0.128	3.512	> 99%
Between locations	5.193	2	2.597	71.088	> 99.95%
Remainder	0.804	22	0.037		

Table 2.3.4. Analysis of variance of ln pCi ^{137}Cs l^{-1} in Faroese milk in 1979 (from Table 2.3.1.A)

Variation	SSD	f	s^2	v^2	P
Between months	1.180	11	0.107	2.784	> 97.5%
Between locations	4.976	2	2.488	64.564	> 99.95%
Remainder	0.848	22	0.039		

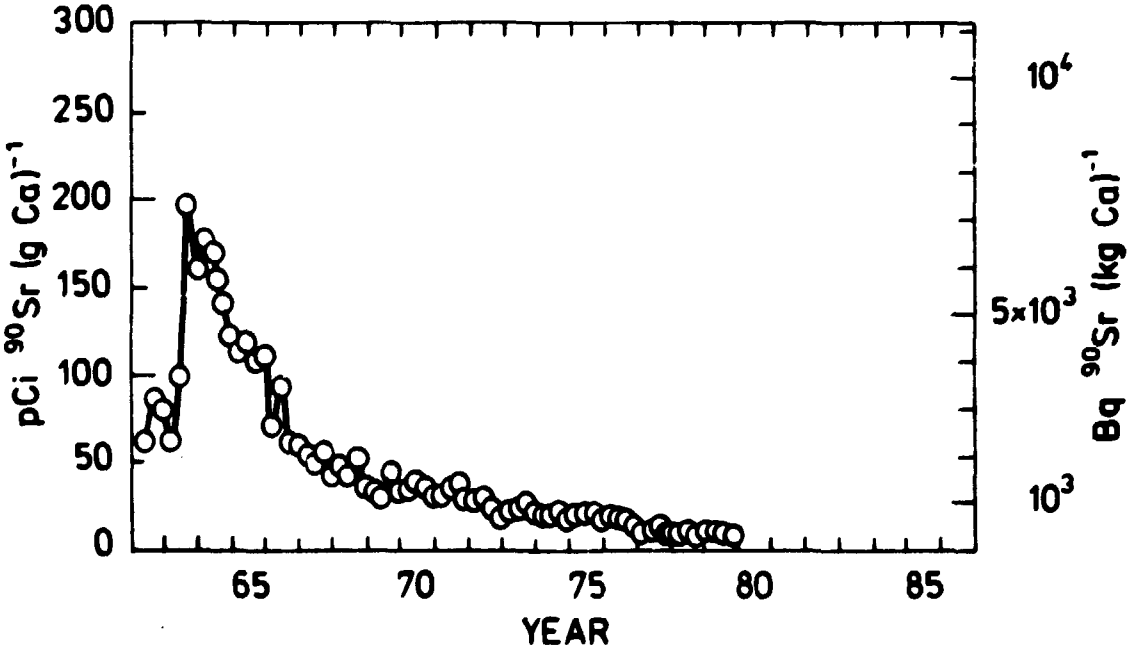

Fig. 2.3.1. Strontium-90 in Faroese milk, 1962-1979.

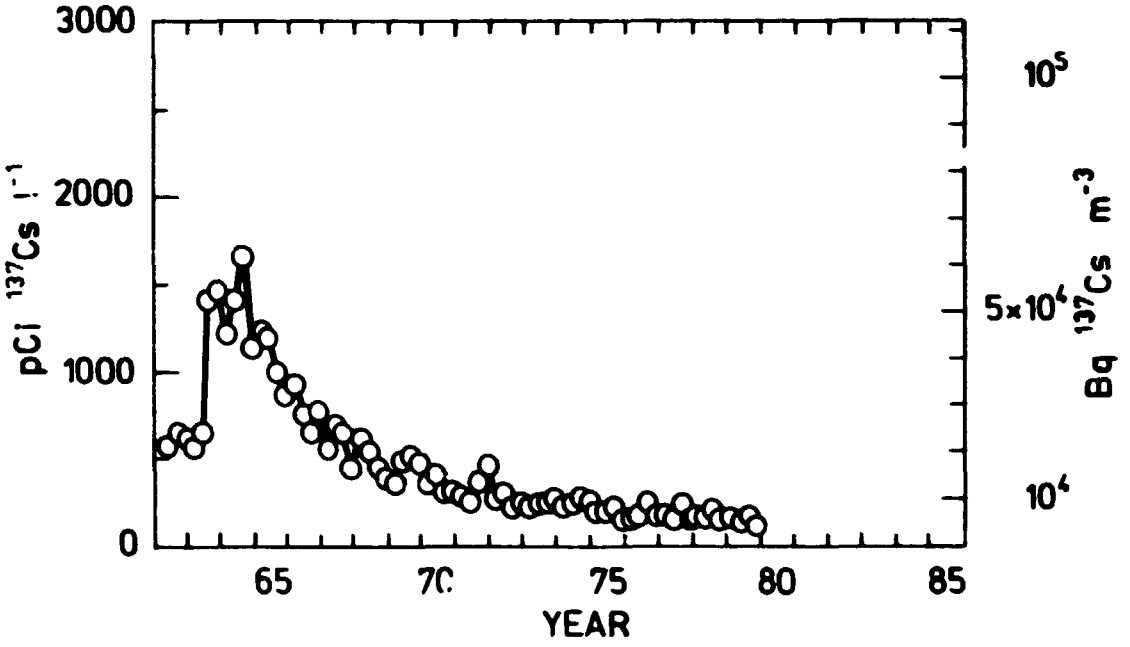

Fig. 2.1.2. Cesium-137 in Faroese milk, 1962-1979.

The annual mean values of the M.U./S.U. ratio in Faroese milk are shown in Fig. 2.3.3.

The mean M.U./S.U. ratio in 1979 was 10.9±0.7 (± SE) during the grazing period (May-October), and in the winter time it was 9.8±0.3.

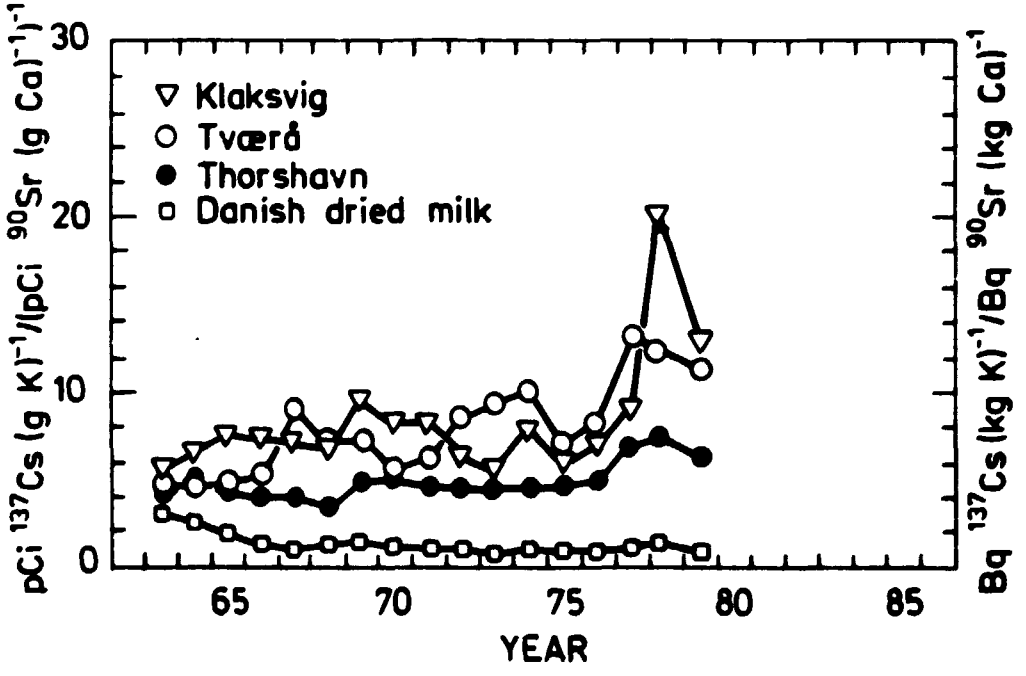

Fig. 2.3.3. $\frac{M.U.}{S.U.}$ ratios in Faroese and Danish milk, 1963-1979.

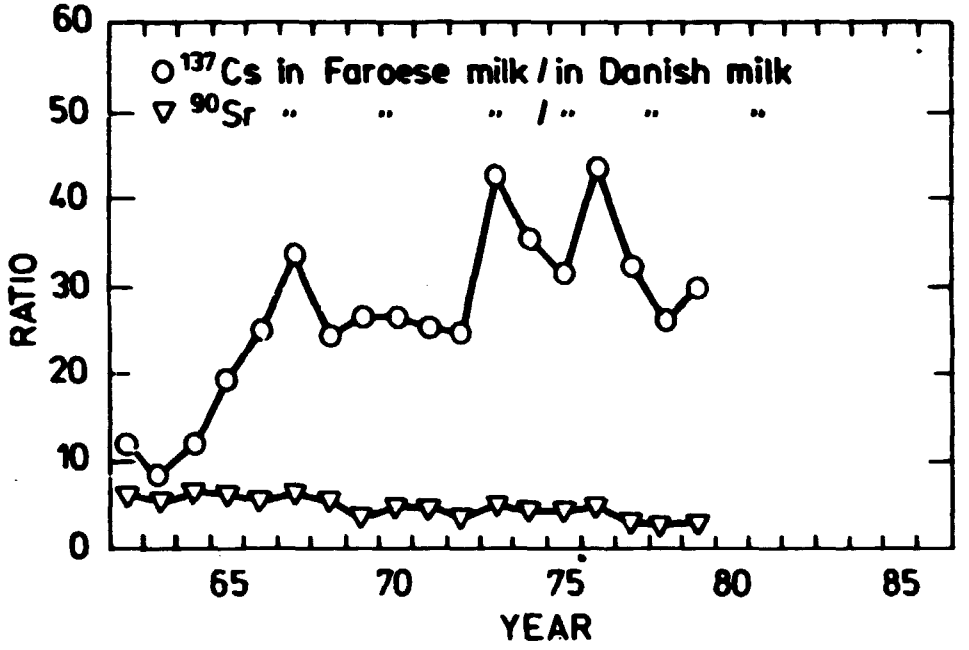

Fig. 2.3.4. A comparison between Faroese and Danish milk levels, 1962-1979.

Figure 2.3.4 shows a comparison between the ^{90}Sr and ^{137}Cs levels in Faroese- and Danish-produced milk. It is evident that indirect contamination plays an important role for the ^{137}Cs levels in the Faroes, because the ratio between ^{137}Cs in Faroese and Danish milk increases with time. The ratios between the ^{90}Sr levels in Faroese and Danish milk have shown a slight tendency to decrease through the years.

An ANOVA of the potassium content in Faroese milk collected since 1964 showed no significant difference between the 3 locations. The variation in time was significant. The mean value was 1.69 g K l^{-1}. The relative standard deviation was 9%.

2.4. Strontium-90 and Cesium-137 in terrestrial animals

The 1979 levels in one sample of mutton were 1.18 pCi ^{90}Sr kg^{-1} or 23 S.U., and 103 pCi ^{137}Cs kg^{-1}, or 35 M.U. The bone level was 18.6 pCi ^{90}Sr (g Ca)$^{-1}$.

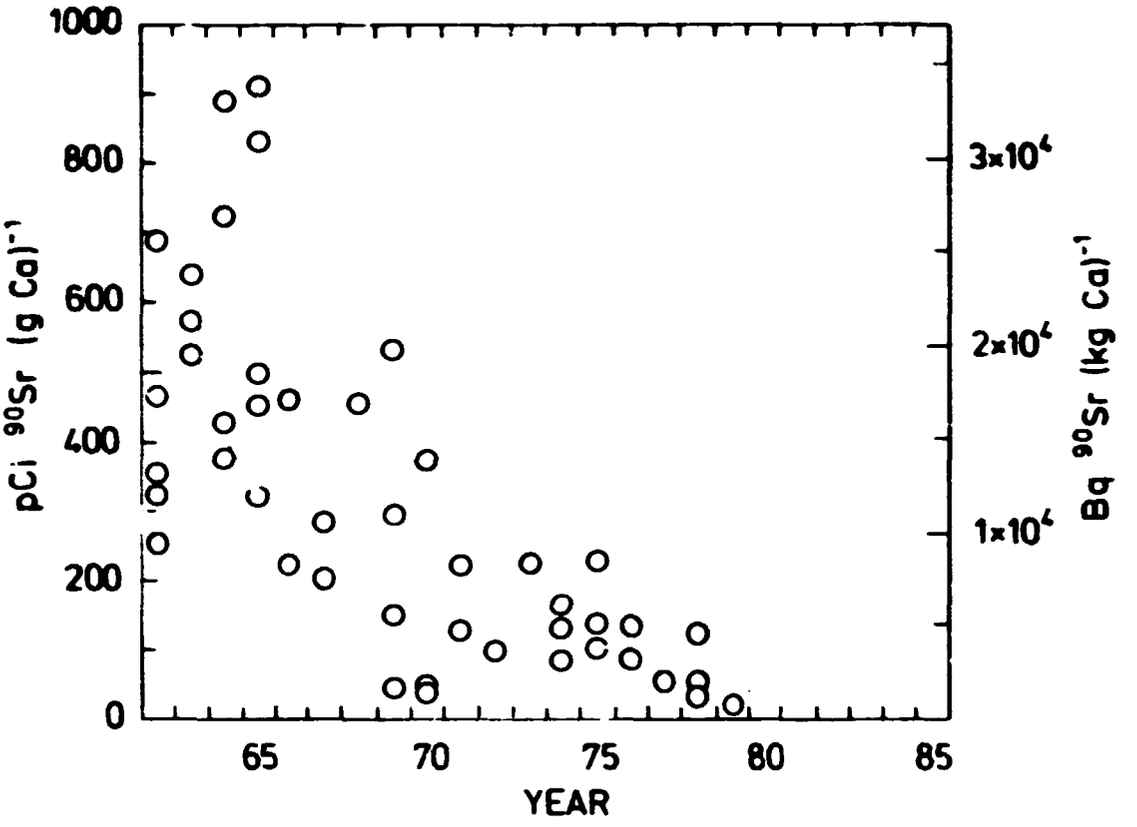

Fig. 2.4.1. Strontium-90 (pCi (g Ca)$^{-1}$) in lamb bone collected in the Faroes, 1962-1979.

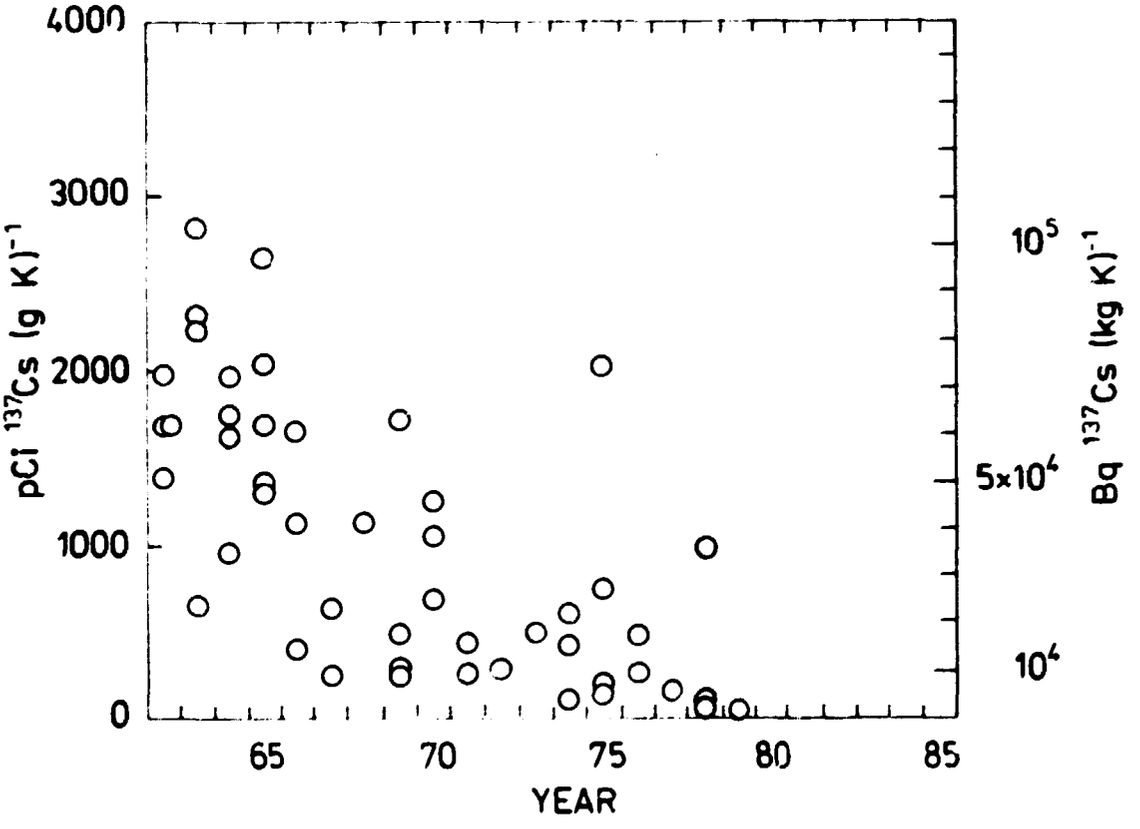

Fig. 2.4.2. Cesium-137 (pCi (g K)$^{-1}$) in lamb meat collected in the Faroes, 1962-1979.

Table 2.5.1.A. Strontium-90 and Cesium-137 in sea animals from the Faroes in 1979

Sampling month	Species	Sample type	pCi ^{90}Sr kg^{-1}	pCi ^{90}Sr (g Ca)$^{-1}$	pCi ^{137}Cs kg^{-1}	pCi ^{137}Cs (g K)$^{-1}$
Jan	Fish Gadus aeglefinus	meat			6.3	1.96
April	" - " -	"			5.3	1.26
June	" - " -	"			4.8	1.03
Sept	" - " -	"			9.1	2.1
Nov	" - " -	"			6.5	1.86
Jan	Fish Gadus callarias	meat			6.6	1.57
April	" - " -	"			9.1	1.85
June	" - " -	"			10.2	2.2
Sept	" - " -	"			13.3	2.60
Nov	" - " -	"			5.5	1.19
Aug	Whale Grind	meat	0.6	4	12.7	3.6
"	- " - "	bone		0.04 B		
Aug	Bird Guillemot I	meat	0.1 B	1.0 B	5.4	1.47
"	" - " - II	"			5.4	1.47
"	" - " - I	bone		0.02 A		
"	" - " - II	"		0.05 A		
"	" Puffin I	meat	0.2 B	1.6 B	8.3	2.4
"	" - " - II	"	0.3 B	1.5 B	10.0	2.4
"	" - " - I	bone		0.03 B		
"	" - " - II	"		0.05		

Table 2.5.1.8. Strontium-90 and Cesium-137 in sea animals from the Faroes in 1979

Sampling month	Species	Sample type	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$
Jan	Fish Gadus aegleginus	meat			0,23	72
April	" - " -	"			0,196	47
June	" - " -	"			0,178	38
Sept	" - " -	"			0,34	78
Nov	" - " -	"			0,24	69
Jan	Fish Gadus callarias	meat			0,24	58
April	" - " -	"			0,34	68
June	" - " -	"			0,38	81
Sept	" - " -	"			0,49	96
Nov	" - " -	"			0,28	44
Aug	Whale Grind	meat	0,01	159	0,47	133
"	" "	bone		1,3 B		
Aug	Bird Guillemot	meat	0,005 B	40 B	0,20	54
"	" - " -	"			0,20	54
"	" - " -	bone		0,9 A		
"	" - " -	"		2,0 A		
Aug	Bird Puffin	meat	0,007 B	60 B	0,31	69
"	" - " -	"	0,01 B	56 B	0,37	69
"	" - " -	bone		1,1 B		
"	" - " -	"		1,7 B		

2.5. Strontium-90 and Cesium-137 in sea animals

Table 2.5.1 shows the ^{137}Cs levels in fish collected in 1979 in the Faroes. The mean levels in Gadus aeglefinus and Gadus callarias were 7.7 pCi ^{137}Cs kg^{-1} (S.E.: 1).

Sea birds (Guillemot and puffin) contained 7.3 pCi ^{137}Cs kg^{-1} and 0.2 pCi ^{90}Sr kg^{-1}. Grind contained 12.7 pCi ^{127}Cs kg^{-1}.

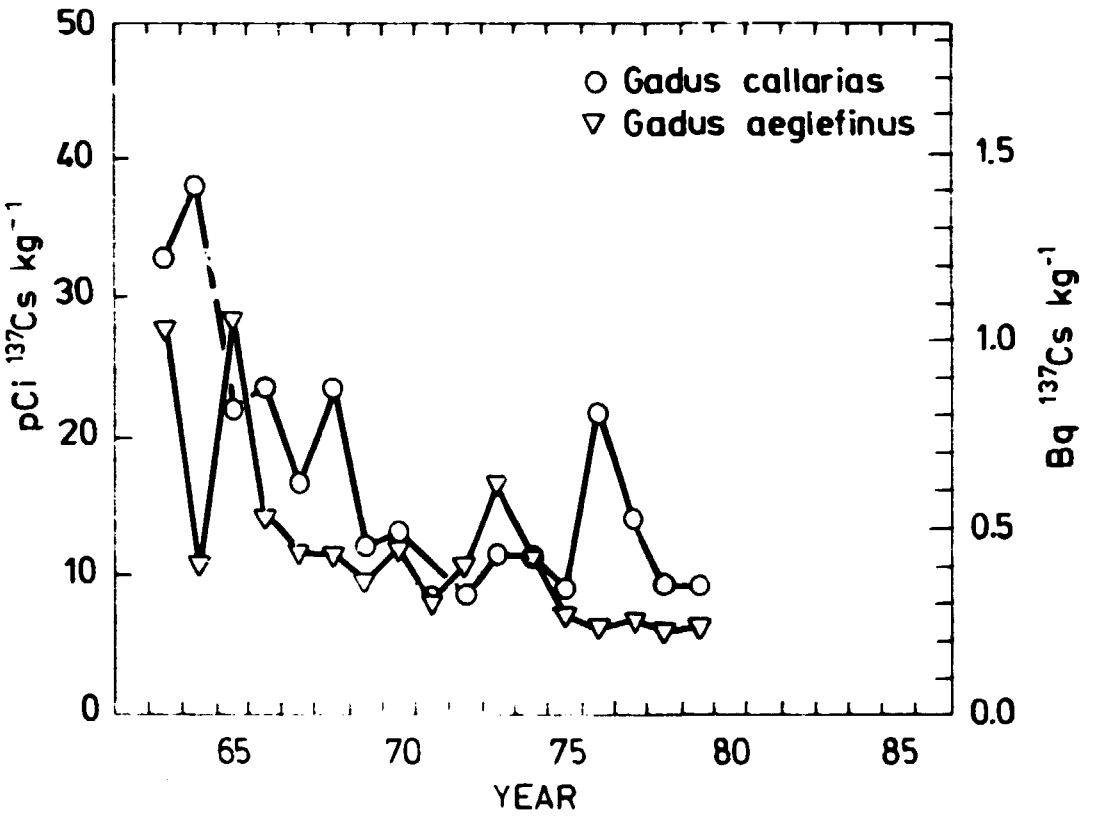

Fig. 2.5.1. Cesium-137 levels in meat of cod (Gadus callarias) and Haddock (Gadus aeglefinus) collected in the Faroes, 1962-1979.

2.6. Strontium-90 in drinking water

Drinking-water samples were collected as previously but the samples were combined before the analysis as shown in Table 2.6.1. As in previous years, drinking water from Thorshavn contained more ^{90}Sr than that from Tvørå (cf. the explanation in Risø Report No. 181[1]).

Table 2.6.1.A. Strontium-90 in drinking water from the Faroes in 1979 (Unit: pCi l^{-1})

	Thorshavn	Klaksvig	Tværå
Jan-June	0.29	0.049	0.160
July-Dec	0.25	0.061	0.145
1979	0.27	0.055	0.152

Table 2.6.1.B. Strontium-90 in drinking water from the Faroes in 1979 (Unit: Bq m^{-3})

	Thorshavn	Klaksvig	Tværå
Jan-June	10.8	1.80	5.9
July-Dec	9.2	2.20	5.4
1979	10.0	2.00	5.6

Figure 2.6.1 shows the annual mean levels of ^{90}Sr in drinking water from the three locations since 1962.

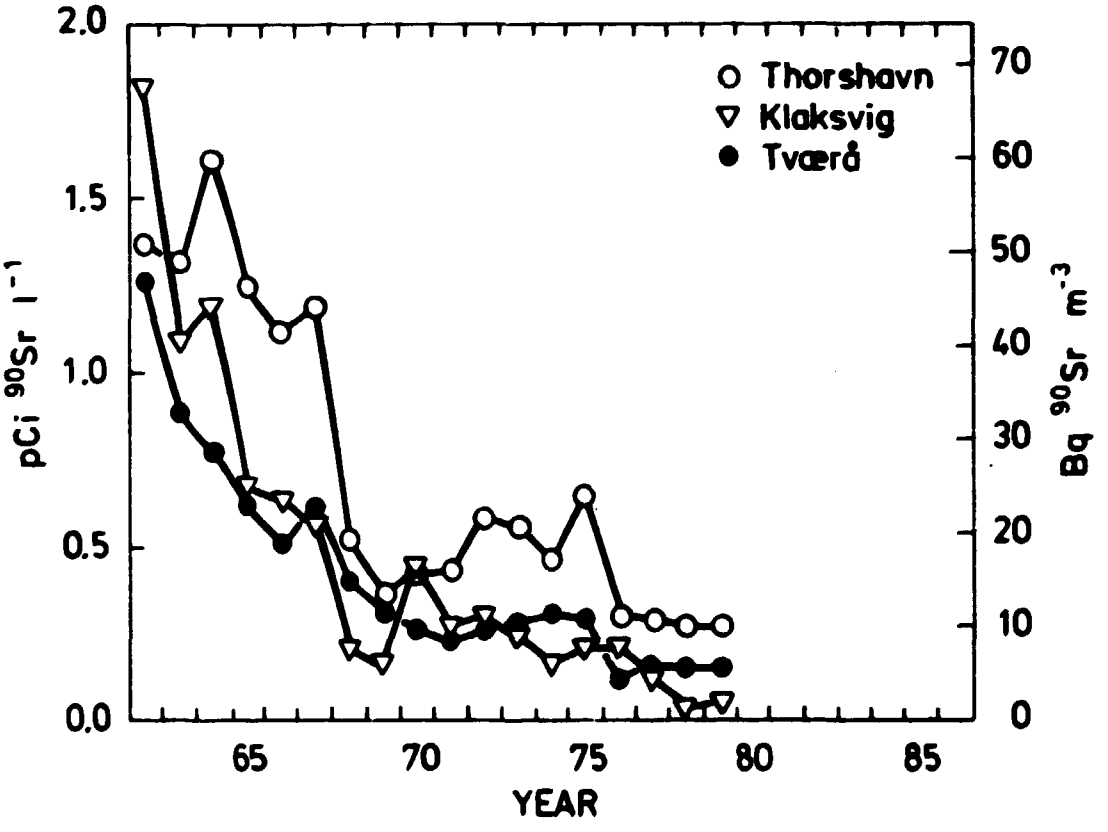

Fig. 2.6.1. Strontium-90 in drinking water from the Faroes, 1962-1979.

The mean level in 1979 was 0.16 pCi $^{90}Sr\ l^{-1}$, i.e. nearly the same as the 1978 level.

2.7. Strontium-90 and Cesium-137 in miscellaneous samples

2.7.1. Soil

No soil samples were collected in 1979 from the Faroes. From earlier years' observations we estimate the accumulated fallout at Thorshavn to be 71 mCi $^{90}Sr\ km^{-2}$ and that at Klaksvig to be 133 mCi $^{90}Sr\ km^{-2}$ (cf. Fig. 2.1).

2.7.2. Sea water

Surface sea water was collected near Thorshavn on two occasions in 1979. The ^{90}Sr mean level was 0.064 pCi $^{90}Sr\ l^{-1}$. (1 S.E.: 0.008).

Figure 2.7.2 shows the ^{90}Sr levels since 1962.

Sea water from August was also analysed for ^{137}Cs. The ^{137}Cs levels in 1979 was 0.14 pCi l^{-1}. The $^{137}Cs/^{90}Sr$ ratio was 2.50, i.e. higher than expected in ocean water. We assume the enhanced ^{137}Cs level to originate from Windscale.

Table 2.7.2.A. Strontium-90 and Cesium-137 in sea water from the Faroes in 1979

Sampling month	pCi $^{90}Sr\ l^{-1}$	pCi $^{137}Cs\ l^{-1}$	Salinity o/oo
March	0.072		36.9
August	0.056	0.14	36.9

Table 2.7.2.B. Strontium-90 and Cesium-137 in sea water from the Faroes in 1979

Sampling month	*Bq $^{90}Sr\ m^{-3}$*	*Bq $^{137}Cs\ m^{-3}$*	*Salinity o/oo*
March	*2.7*		*36.9*
August	*2.1*	*5.2*	*36.9*

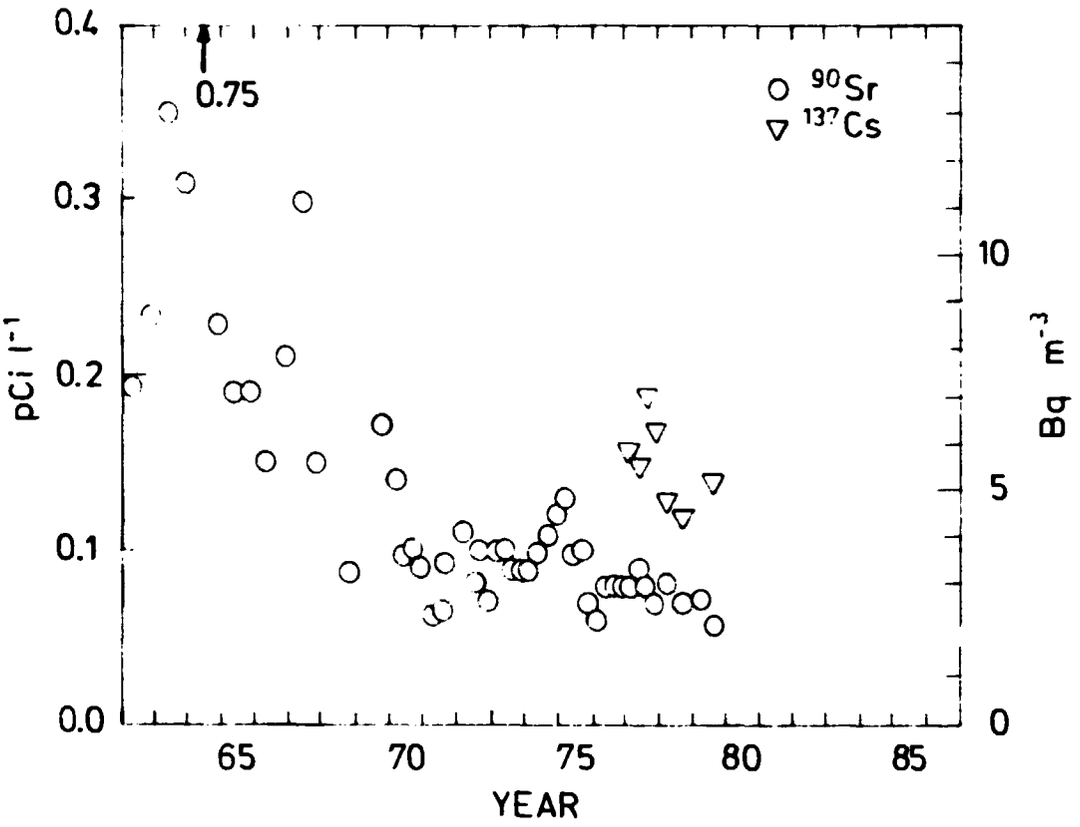

Fig. 2.7.2. Strontium-90 and Cesium-137 in Faroese sea water, 1962-1979.

2.7.3. Sea plants

Two samples of sea weed were analysed in 1979. Table 2.7.3 shows the ^{90}Sr and the ^{137}Cs determinations.

As compared with Danish fucoids in 1979[2)] the Faroese $^{137}Cs/K$ level was 15 times lower. If we assume the same concentration factors between fucoids and sea water at the Faroes as in Danish waters, we may assume that the Faroese sea water contained 15 times less ^{137}Cs than the Danish, which (at the fucoid locations) contained 1.7±0.4 (1 SD) pCi ^{137}Cs l^{-1}. Hence the predicted ^{137}Cs level in Faroese water was 0.11±0.03 pCi ^{137}Cs l^{-1}, and we measured 0.14.

Table 2.7.3.A. Strontium-90 and Cesium-137 in sea plants from the Faroes in 1979

Species	Sampling month	pCi ^{90}Sr (kg ash)$^{-1}$	pCi ^{90}Sr (g Ca)$^{-1}$	pCi ^{137}Cs (kg ash)$^{-1}$	pCi ^{137}Cs (g K)$^{-1}$
Laminaria Hyperborea	April	470	5.4	105 A	0.54 A
Fucus vesiculosus	Sept	105	1.75	220	0.73

Table 2.7.3.B. Strontium-90 and Cesium-137 in sea plants from the Faroes in 1979

Species	Sampling month	Bq ^{90}Sr (kg ash)$^{-1}$	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs (kg ash)$^{-1}$	Bq ^{137}Cs (kg K)$^{-1}$
Laminaria Hyperborea	April	17.4	200	3.9 A	20 A
Fucus vesiculosus	Sept	3.9	65	8.1	27

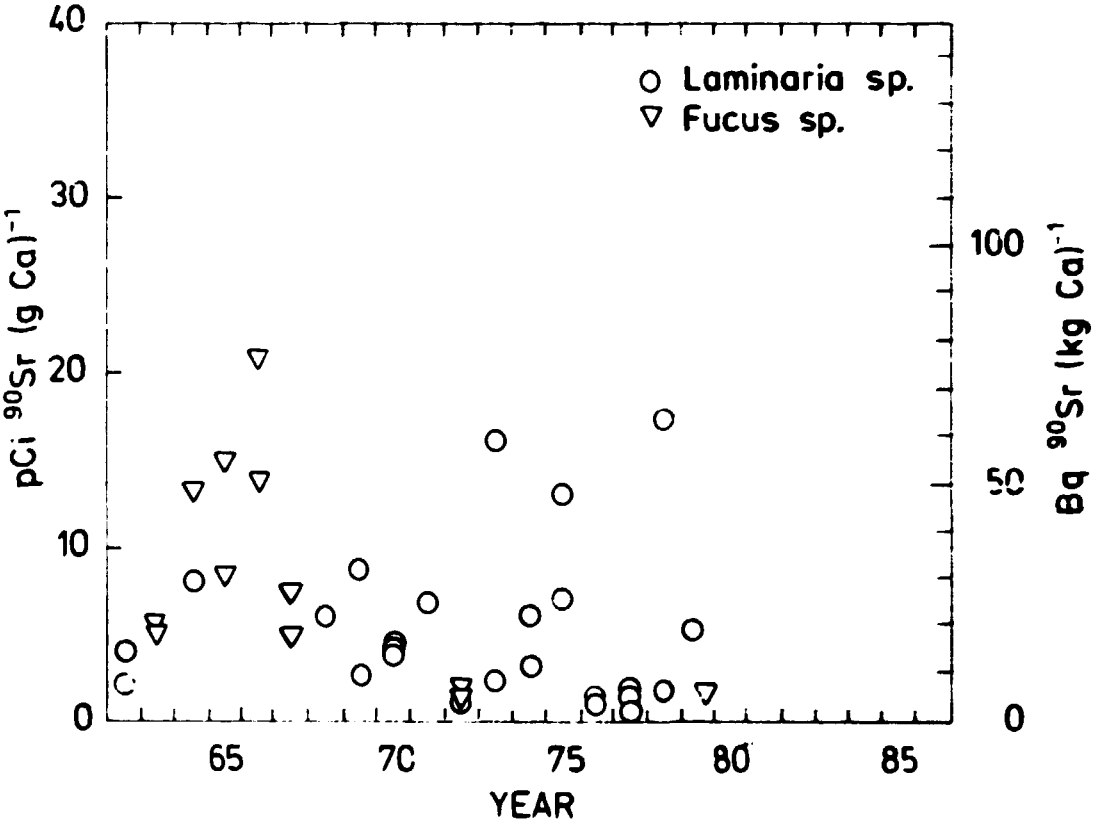

Fig. 2.7.3. Strontium-90 (pCi (g Ca)$^{-1}$) in sea plants collected at Thorshavn, 1962-1979.

2.7.4. Vegetables

Table 2.7.4 shows the results of the ^{90}Sr and ^{137}Cs determinations.

Table 2.7.4.A. Strontium-90 and Cesium-137 in vegetables and potatoes from the Faroes in September 1979

Species	Location	pCi ^{90}Sr kg^{-1}	pCi ^{90}Sr (g Ca)$^{-1}$	pCi ^{137}Cs kg^{-1}	pCi ^{137}Cs (g K)$^{-1}$
Cabbage*		14.2	40	11.4	3.4
Beet		15.6	60	26	9.2
Potatoes	Thorshavn	5.8	220	76	17.4

*White cabbage and cauliflower.

Table 2.7.4.B. Strontium-90 and Cesium-137 in vegetables and potatoes from the Faroes in September 1978

Species	Location	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$
Cabbage*		0.52	1400	0.42	110
Beet		0.58	2200	0.96	360
Potatoes	Thorshavn	0.21	8000	2.7	640

*As for cabbage and cauliflower.

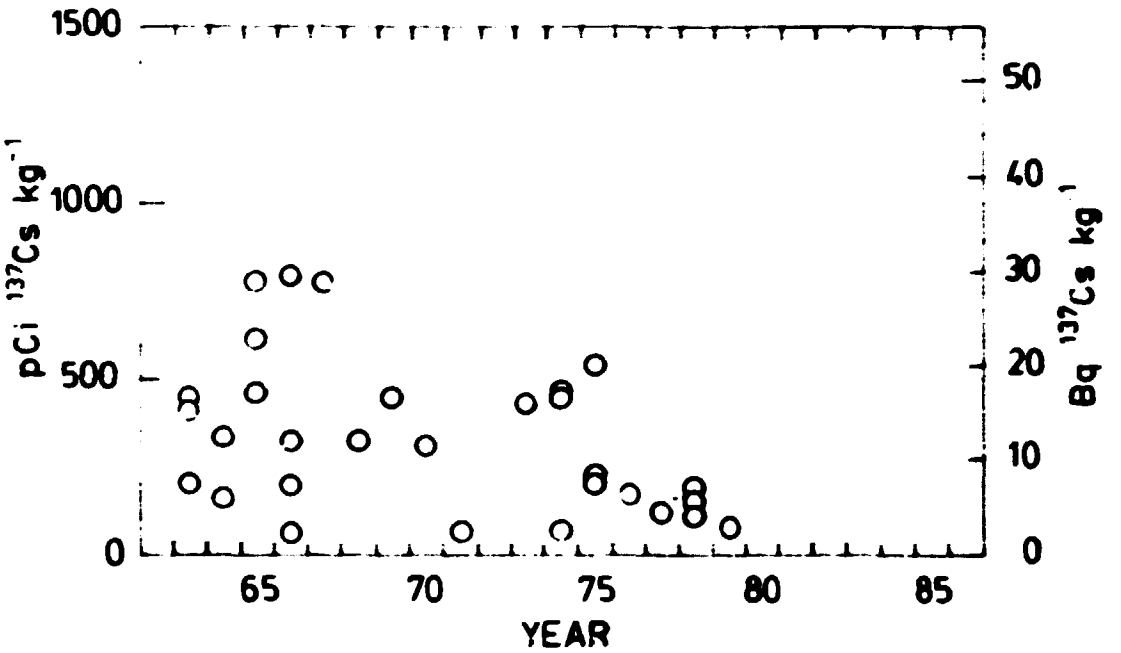

Fig. 2.7.4.1. Cesium-137 in Faroese potatoes, 1962-1979.

The ^{137}Cs level in potatoes (74 pCi kg^{-1}) was lower than that observed in 1978, and the ^{90}Sr level (5.8 pCi kg^{-1}) was lower too. The ^{90}Sr level in cabbage was close to the Danish level[2] while the ^{137}Cs level was 5 times higher in the Faroes produce.

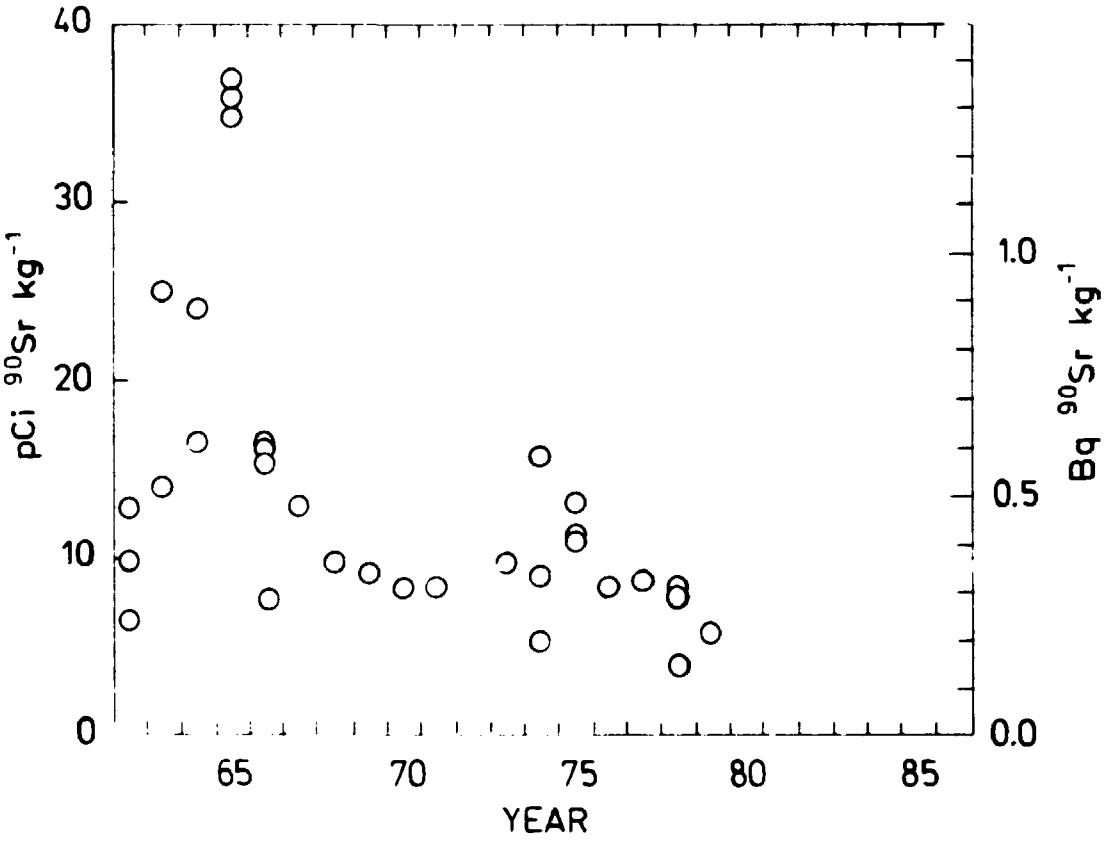

Fig. 2.7.4.2. Strontium-90 in Faroese potatoes, 1962-1979.

2.7.5. Bread

As in previous years[1], rye bread and white bread were collected at Thorshavn in June and December. The mean levels in white bread were 5.0 pCi ^{90}Sr kg^{-1} and 5.4 pCi ^{137}Cs kg^{-1}. The rye bread collected in 1979 contained on the average 10.9 pCi ^{90}Sr kg^{-1} and 11.5 pCi ^{137}Cs kg^{-1}, i.e. the bread levels were for ^{90}Sr a little higher than the 1978 levels and the ^{137}Cs levels were lower than the 1978 levels.

The ^{137}Cs and ^{90}Sr levels in Faroese bread were generally lower than the corresponding Danish[2].

Table 2.7.5.A. Strontium-90 and Cesium-137 in Faroese bread in 1979

Month	Sort	pCi ^{90}Sr kg^{-1}	pCi ^{90}Sr (g Ca)$^{-1}$	pCi ^{137}Cs kg^{-1}	pCi ^{137}Cs (g K)$^{-1}$
June	White bread	4.0	5.8	7.0	4.6
June	Rye bread	8.8	4.9	16.0	7.3
Dec	White bread	6.0	23	3.7	2.5
Dec	Rye bread	13.0	5.5	7.0	2.9

Table 2.7.5.B. Strontium-90 and Cesium-137 in Faroese bread in 1979

Month	*Sort*	*Bq ^{90}Sr kg^{-1}*	*Bq ^{90}Sr (kg Ca)$^{-1}$*	*Bq ^{137}Cs kg^{-1}*	*Bq ^{137}Cs (kg K)$^{-1}$*
June	*White bread*	*0.149*	*210*	*0.26*	*171*
June	*Rye bread*	*0.33*	*180*	*0.59*	*270*
Dec	*White bread*	*0.22*	*840*	*0.138*	*91*
Dec	*Rye bread*	*0.48*	*200*	*0.26*	*108*

2.7.6. Eggs

Eggs were collected from Thorshavn in June and December 1979. Table 2.7.6 shows the results. The mean levels of hens eggs were 2.0 pCi ^{90}Sr kg^{-1} (3.5 S.U.) and 3.4 pCi ^{137}Cs kg^{-1}.

Table 2.7.6.A. Strontium-90 and Cesium-137 in hens eggs from the Faroes in 1979

Month	pCi ^{90}Sr kg^{-1}	pCi ^{90}Sr (g Ca)$^{-1}$	pCi ^{137}Cs kg^{-1}	pCi ^{137}Cs (g K)$^{-1}$
June	3.3	5.7	6.9	4.9
Dec	0.71	1.35	B.D.L.	B.D.L.

Table 2.7.6.B. Strontium-90 and Cesium-137 in hens eggs from the Faroes in 1979

Month	*Bq ^{90}Sr kg^{-1}*	*Bq ^{90}Sr (kg Ca)$^{-1}$*	*Bq ^{137}Cs kg^{-1}*	*Bq ^{137}Cs (kg K)$^{-1}$*
June	*0.123*	*210*	*0.25*	*181*
Dec	*0.026*	*50*	*B.D.L.*	*B.D.L.*

2.8. Humans

2.8.1. Strontium-90 in human bone

In 1979 five human bone samples representing 6 individuals from Dronning Alexandrine's Hospital in Thorshavn were analysed. Table 2.8.1 shows the results.

The mean level in bone of newborn infants was 1.23±0.32 (1 SE) pCi ^{90}Sr (g Ca)$^{-1}$. One of the adult bone samples in Table 2.8.1 showed a remarkably high ^{90}Sr content (24 pCi ^{90}Sr (g Ca)$^{-1}$); the observed bone level corresponds to a diet mean level in the

Table 2.8.1.A. Strontium-90 in human vertebrae collected in the Faroes in 1979

Age	Month of death	Sex	pCi ^{90}Sr (g Ca)$^{-1}$	
0	3	M	0.91*	B
0	12	F	1.55	A
3 months	6	M	2.18	
55 years		F	2.42**	
78 years		F	24 **	

* 2 samples combined in one analysis.

**Femur (from amputation).

Table 2.8.1.B. Strontium-90 in human vertebrae collected in the Faroes in 1979

Age	Month of death	Sex	Bq ^{90}Sr (kg Ca)$^{-1}$	
0	3	M	34*	B
0	12	F	57	A
3 months	6	M	81	
55 years		F	90**	
78 years		F	890**	

* 2 samples combined in one analysis.

**Femur (from amputation).

last decade of approx. 150 pCi ^{90}Sr (g Ca)$^{-1}$. Special diet habits and consumption of locally produced food could possibly have resulted in such a high diet content of ^{90}Sr.

In general the Faroese bone levels correspond to the estimated diet levels as given in Fig. 3.

3. ESTIMATE OF THE MEAN CONTENTS OF ^{90}Sr AND ^{137}Cs IN THE HUMAN DIET

3.1. Annual quantities

The annual quantities are still based on the estimate made by Professor E. Hoff-Jørgensen, Ph.D., in 1962[1] assuming a daily per caput intake of approx. 3000 calories (12.6 Mj).

3.2. Milk and cream

75% of the milk consumed in the Faroes is assumed to be of local origin, and 25% comes from Denmark. Hence the ^{90}Sr content in milk consumed in the Faroes in 1979 was $1.2 \cdot (0.75 \cdot 8.4 + 0.25 \cdot 2.9) = 7.0$ pCi ^{90}Sr kg^{-1}, and the ^{137}Cs content was $0.75 \cdot 151 + 0.25 \cdot 4.8 = 114$ pCi ^{137}Cs kg^{-1} (cf. 2.3 and ref. 2). 1 kg milk contains 1.2 g Ca.

3.3. Cheese

Nearly all cheese consumed in the Faroes is of Danish origin, and the Danish figures from ref. 2 were used: 24.6 pCi ^{90}Sr kg^{-1} and 3.5 pCi ^{137}Cs kg^{-1}.

3.4. Grain products

As most grain products are imported from Denmark, the Danish figures for 1979[2] were used in the calculation of the Faroese levels. The mean daily consumption of grain products in the Faroes is, as in Denmark, 80 g rye flour, 120 g wheat flour, and 20 g grits. Hence the mean concentration of ^{90}Sr in grain products consumed in the Faroes in 1979 is 11.4 pCi ^{90}Sr kg^{-1} and 17.5 pCi ^{137}Cs kg^{-1}.

3.5. Potatoes

All potatoes consumed in the Faroes are assumed to be of local origin. The values from Table 2.7.4 were used, i.e. 5.8 pCi ^{90}Sr kg^{-1} and 74 pCi ^{137}Cs kg^{-1}.

3.6. Other vegetables and fruit

As the amount of vegetables and fruit grown in the Faroes is limited, the Danish figures from 1979[2)] were used. Thus the mean contents in vegetables other than potatoes were 6.9 pCi ^{90}Sr kg^{-1} and 1.7 pCi ^{137}Cs kg^{-1}, and the mean contents in fruit were 1.5 pCi ^{90}Sr kg^{-1} and 1.7 pCi ^{137}Cs kg^{-1}.

3.7. Meat and eggs

Meat and egg consumption in the Faroes is estimated to consist of 50% locally produced mutton (or lamb), 25% local whale meat, and 25% sea birds and eggs.

The mutton contained 1.2 pCi ^{90}Sr kg^{-1} and 103 pCi ^{137}Cs kg^{-1} (cf. 2.4). Whale meat from 1979 contained 0.6 pCi ^{90}Sr kg^{-1} and 13 pCi ^{137}Cs kg^{-1}, sea birds from 1979 and eggs (cf. 2.7.6): 0.2 pCi ^{90}Sr kg^{-1} and 2 pCi ^{90}Sr kg^{-1}, and 7.3 and 2.5 pCi ^{137}Cs kg^{-1} respectively.

Hence we estimate the mean content of ^{90}Sr in meat and eggs consumed in 1979 to be

$$0.50 \cdot 1.2 + 0.25 \cdot 0.6 + 0.25 \cdot \left(\frac{0.2+2.0}{2}\right) = 1.0 \text{ pCi } ^{90}Sr \text{ } kg^{-1}$$

and the ^{137}Cs content to be

$$0.50 \cdot 103 + 0.25 \cdot 13 + 0.25 \cdot \left(\frac{7.3+2.5}{2}\right) = 56 \text{ pCi } ^{137}Cs \text{ } kg^{-1}.$$

3.8. Fish

All fish consumed in the Faroes is of local origin, and the mean contents in fish, obtained from subsection 2.5, were 0.24 pCi $^{90}Sr\ kg^{-1}$ and 7.7 pCi $^{137}Cs\ kg^{-1}$. The ^{90}Sr level was that from 1978.

3.9. Coffee and tea

The Danish figures for 1978[2)] were used, i.e. 29 pCi $^{90}Sr\ kg^{-1}$ and 71 pCi $^{137}Cs\ kg^{-1}$.

3.10. Drinking water

The mean value found in Table 2.6.1 was used, i.e. 0.16 pCi $^{90}Sr\ l^{-1}$. The ^{137}Cs content was estimated to be approx. one

Table 3.1. Estimate of the mean content of ^{90}Sr in the human diet in the Faroes in 1979

Type of food	Annual quantity in kg	pCi ^{90}Sr per kg	Total pCi ^{90}Sr	Percentage of total pCi ^{90}Sr in food
Milk and cream	146	7.0	1022	32.3
Cheese	7.3	24.6	180	5.7
Grain products	80	11.4	912	28.8
Potatoes	91	5.8	528	16.7
Vegetables	20	6.9	138	4.3
Fruit	18	1.5	27	0.8
Meat and eggs	37	1.0	37	1.2
Fish	91	0.24	22	0.7
Coffee and tea	7.3	29	212	6.7
Drinking water	548	0.16	88	2.8
Total			3166	

The mean annual calcium intake is estimated to be 600 g (approx. 200-250 g of creta praeparata). Hence the pCi $^{90}Sr\ (g\ Ca)^{-1}$ ratio in the total Faroese diet was 5.3 S.U., and the mean daily intake was 8.7 pCi ^{90}Sr.

Table 3.2. Estimate of the mean content of ^{137}Cs in the human diet in the Faroes in 1979

Type of food	Annual quantity in kg	pCi ^{137}Cs per kg	Total pCi ^{137}Cs	Percentage of total pCi ^{137}Cs in food
Milk and cream	146	114	16644	59.1
Cheese	7.3	3.5	26	0.1
Grain products	80	17.5	1400	5.0
Potatoes	91	74	6734	23.9
Vegetables	20	1.7	34	0.1
Fruit	18	1.7	31	0.1
Meat and eggs	37	56	2072	7.3
Fish	91	7.7	701	2.5
Coffee and tea	7.3	71	518	1.8
Drinking water	548	0.04	22	0.1
Total			28182	

The mean annual intake of potassium is estimated to be approx. 1200 g. Hence the pCi ^{137}Cs $(g\ K)^{-1}$ ratio becomes 23.5 and the daily intake of ^{137}Cs 77 pCi.

fourth (the ratio found in New York tap water in 1964[4]) of the ^{90}Sr content, i.e. 0.04 pCi ^{137}Cs 1^{-1}.

Tables 3.1 and 3.2 show the diet estimates of ^{90}Sr and ^{137}Cs respectively.

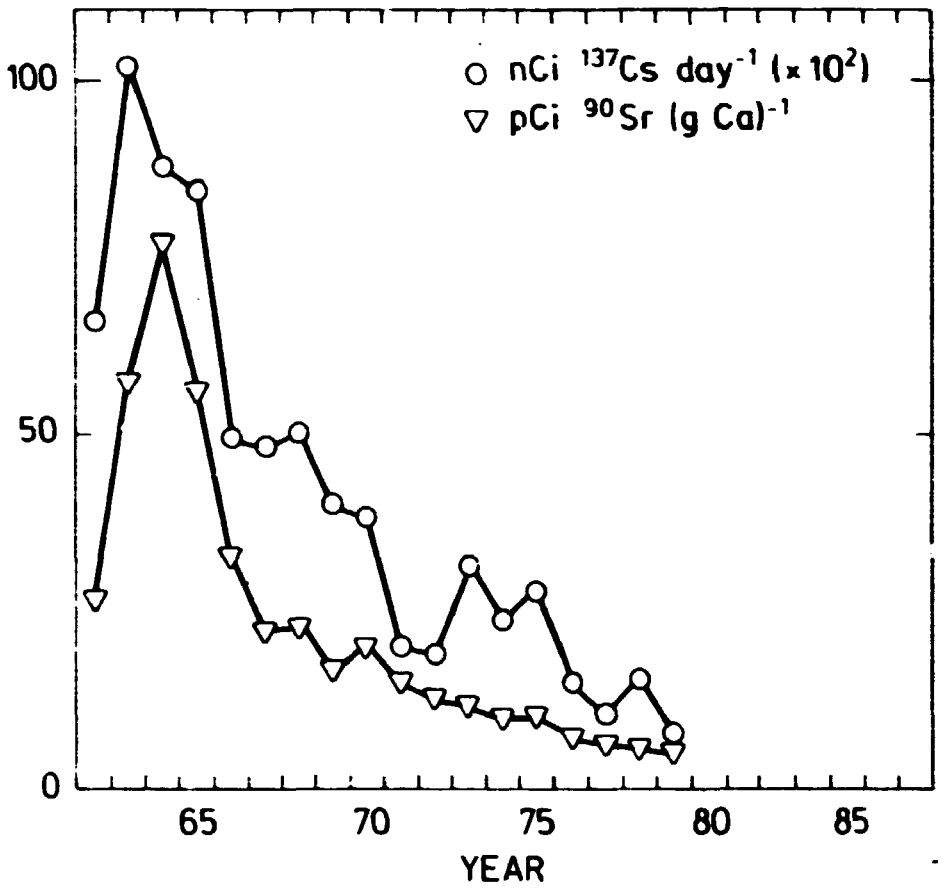

Fig. 3. Strontium-90 and Cesium-137 in Faroese diet, 1962-1979.

3.11. Discussion

Figure 3 shows the Faroese diet levels since 1962.

The 1979 ^{90}Sr level in the total diet was 87 of the 1978 concentration, and the ^{137}Cs level was 50% of that observed in 1978.

The main contributors to the ^{90}Sr content in the Faroese diet were milk products, cereals and potatoes, which together accounted for approx. 84% of the total ^{90}Sr content in the diet in 1979. As regards ^{137}Cs, milk products, meat (lamb) and potatoes were the most important contributors. In 1979, 90% of the total ^{137}Cs content in the diet originated from these products.

The Faroese mean diet contained 1.3 times as much ^{90}Sr and approx. 6 times as much ^{137}Cs as the Danish diet in 1979[2].

4. CONCLUSION

4.1.

The ^{90}Sr fallout rate in the Faroes in 1979 was approx. 0.5 mCi $^{90}Sr\ km^{-2}$. The accumulated fallout by the end of 1979 was estimated at approx. 102 mCi $^{90}Sr\ km^{-2}$ (the mean at Thorshavn and Klaksvig).

4.2.

The mean level of ^{90}Sr in Faroese milk was 8.4 S.U. or 10 pCi $^{90}Sr\ l^{-1}$. The ^{137}Cs concentration was 151 pCi $^{137}Cs\ l^{-1}$.

Mutton contained 1.2 pCi $^{90}Sr\ kg^{-1}$ and 103 pCi $^{137}Cs\ kg^{-1}$. Fish showed a mean level of 7.7 pCi $^{137}Cs\ kg^{-1}$.

The mean content of ^{90}Sr in drinking water was 0.16 pCi l^{-1}.

The mean daily per capita intakes resulting from the Faroese diet in 1979 were estimated at 8.7 pCi ^{90}Sr (5.3 S.U.) and 77 pCi ^{137}Cs (23.5 pCi $^{137}Cs\ (g\ K)^{-1}$).

4.3.

From the Faroese and Danish diet estimates and from measurements on Faroese and Danish bones, the Faroese bone levels in 1979 were estimated as follows: in newborn infants: approx. 1 S.U.; in small children (1 month-4 years): approx. 1-2 S.U. (depending upon the amount of locally produced milk in the diet of the infants); in children and teenagers (5-19 years): approx. 1-2 S.U.; in adult vertebrae: approx. 1-2 S.U.

The mean content of ^{137}Cs in the Faroese adult was estimated at approx. 100 pCi $^{137}Cs\ (g\ K)^{-1}$. This estimate is based on the diet estimate.

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